Brass Tacks

An in-depth look at a radio-related topic

Switches

When I enter my study, I flip a switch to complete a circuit that provides electrical power to the room light. Then, I sit down at my computer and press another switch to turn it on. After a minute of starting up, I move the mouse and press another switch, a mouse click. I then begin pressing a few dozen switches in the form of keys on my keyboard as I compose an email to somebody. When I click Send, the action starts the computer software into a series of operations that require the computer's central processing unit to turn millions of switches on and off in billionths of seconds.

The ***electrical switch*** is found nearly everywhere there's an electrical circuit; its primary purpose is to either complete or interrupt the path of electrical current. If the switch completes the electrical current path, we refer to it as being ***closed***, and if the switch interrupts the path, we refer to it as being ***open***. A switch is possibly the simplest electrical component to build or manufacture, but some switches can be very complex. Many are mechanical (have moving parts), like my light switch; many are not, like those in transistor circuits.

Switches are available in more types, styles, and varieties than probably any other electrical component. Perhaps the majority of mechanical switches in existence are used to complete a path for electrical power, but there are many that are used to connect other types of electrical pathways, such as the PTT (push-to-talk) button on your microphone or the keys on your computer keyboard. Note that this discussion does not include a Nintendo Switch. :-)

Poles and throws

Picture, if you will, a knife switch that's being thrown to apply lightning energy to Dr. Frankenstein's monster or to somebody sitting in a chair at the Florida State Prison. The hinge of the knife switch is referred to as its ***pole***, like the point where a pole-vaulter might place the pole as an anchor point, to allow the athlete and the rest of the pole to swing up and over to the other side. The "swing" action of the knife switch making a contact is referred to as its ***throw***, like the pole action of the pole-vaulter *throwing* the athlete over the bar.

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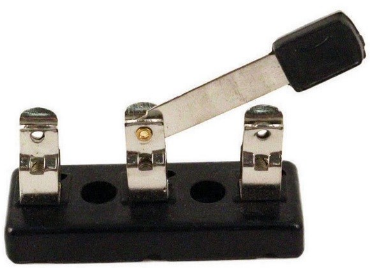
Because the above knife switch has only one hinge point, we say that it's a ***single-pole switch***. And because the blade of the knife switch can only swing toward one side to make a contact, we say that it's a ***single-throw switch***. Together, we call this a ***single-pole, single-throw switch***, and we often abbreviate that to ***SPST***.

Of course, a switch can have a single pole, or a single point of electrical source, but can swing two ways, making contact on one side or the other. We therefore call this a ***single-pole, double-throw switch***, which we abbreviate to ***SPDT***. A switch can have two points of contacts, so that it can provide an electrical signal from two sources, so we call this a ***double-pole switch***. You can imagine the many switch types that can be made from the combinations of poles and throws.



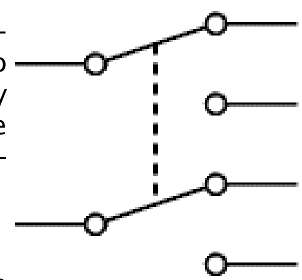
SPDT switch

DPST switch

DPDT switch

TPDT switch

In these knife switch varieties, you can see that the DPDT switch, for example, is simply made of two separate SPDT switches, only the two "knife blades" are permanently attached to each other, such that they always swing or throw together. We say that the two switches are ***ganged*** (they "gang" up), meaning that a single physical operation results in affecting multiple circuit paths.



DPDT switch symbol, ganged connection dotted

Making and breaking

My base station radio is normally powered by a power supply that's plugged into the wall socket. Yet if my house power goes out, in under a minute I can easily unplug my radio from the power supply and plug it into a battery. Even better, I can connect a DPDT switch, whose poles are connected to my radio, and whose one side pair is connected to the power supply and the other side pair is connected to the battery. When I throw the switch, I've now reduced the time that the radio switches its electricity source from commercial power to battery power from under a minute to a few seconds.

This way, because I **break** the connection with the power supply before I **make** the connection with the battery, we call this operation ***break-before-make***, the most common type for physical switches. It allows two different circuits to remain completely isolated during the switching process. But even a few seconds means my radio will be turned off, then turned on again, interrupting what I'm hearing, or even disrupting my transmission.

Instead, I might prefer to somehow switch from one power source to another one without turn-

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continued

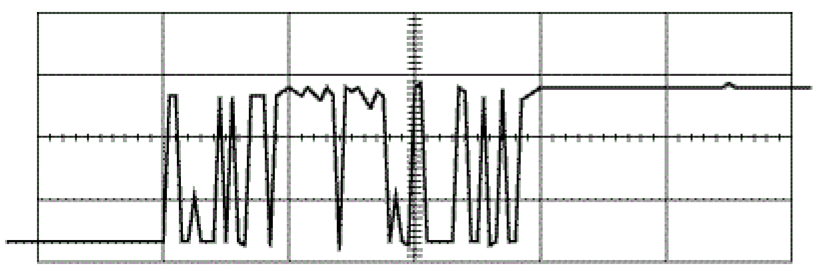
ing off the power to my radio. That means I momentarily **make** the connection to my battery before I **break** the connection to my power supply. Therefore, this type of switch operation is known as ***make-before-break***, which allows my radio to run *continuously uninterrupted*. Its main disadvantage, of course, is that the two power circuits come in contact with each other for a very short period of time, which needs to be taken into consideration during design.

Most UPS (uninterruptible power supply) units use the make-before-break operation to switch between commercial power and battery power and provide the continuous, uninterrupted electrical energy they're known for. Obviously, this can become a life-saving feature for medical equipment or even entire hospital wings. It's also used by a *transfer switch*, which allows a home to switch between commercial power and generator power or solar power almost unnoticeably.

Switch bounce

When a physical switch closes, the contacts don't always connect smoothly because they're made of actual materials, typically a metal. If you were to observe this connection microscopically and in very slow motion, you'd likely see the contacts touch, then rebound off each other, then touch again, repeating the cycle until they come into full contact, like a basketball repeatedly bouncing on the driveway until it rests on the concrete.

This undesirable action is known as ***bounce***, and can wreak havoc on a circuit that depends on a constant voltage level. If the switch is connected to the input of a logic circuit, for example, its signal could be interpreted as a 1, then a 0, then a 1, another 1, etc., until the switch stops bouncing. The result is a signal stream of random ones and zeroes (and indeterminate states!) in rapid succession, and can appear like the following on an oscilloscope:



Imagine what would result if this switch was flipped by a person at a voting booth : the candidate might get more than a dozen votes! Solving the problem of bounce requires a circuit that captures the first transition to the opposite state, and outputs a signal of that state until the switch has settled into its final state. We call that *switch debouncing*, and one popular, effective, and inexpensive device used for switch debouncing is the Schmitt trigger.

Ideal switch

Real-life switches seem nearly perfect for the functions they perform in many respects, but they exhibit limitations that sometimes need to be taken into account for specialized circuits. An *ideal switch* might be one that exhibits no voltage drop, zero rise and fall times, no bounce, no voltage or current limit, and zero resistance. For most applications, the non-ideal behaviors are negligible, and so produce no meaningful effect on the circuits or signals they

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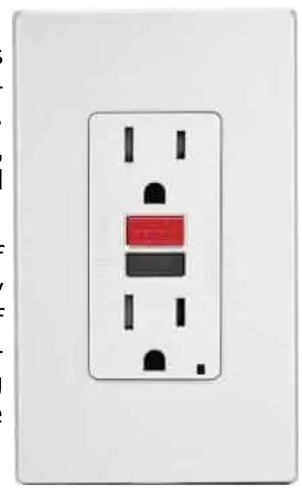
attempt to connect.

But real-life physical switches bounce, have slightly oxidized contacts, and can only carry a finite amount of current. If you measure the resistance across two contacts of a new switch in its closed position, your meter might display a very low value, maybe something along the lines of 0.00005 ohms, if it's even capable of that fine of measurement.

After a few years of use, however, that same switch might read 2.1 ohms, 42,000 times the original value! Oxidation and carbon buildup due to arcing, oils spreading from internal joints, and environmental contaminants, such as dust, moisture, and microbes collect and partially interrupt the formerly clean path. The minimum amount of current required to overcome the oxidation is known as the *wetting current*. If the applied voltage is sufficiently high, this increase in resistance could result in warming the switch to the point of actually causing a fire, damaging not only the switch but whatever it's attached to, such as your house.

Circuit breaker

Somewhere in your house, an electrical panel contains a couple of columns of switches, each of which typically remains closed (connected) until an undesirable event triggers it to open. A *circuit breaker* is an automatically operated switch that permits current to flow through it until a threshold of current is reached, after which the switch is opened, "breaking" the home circuit to which it normally supplies the power. An ordinary circuit breaker will open if a current exceeding 10 amperes to 20 amperes appears on its household circuit.



A special case of a circuit breaker is the *GFCI breaker* which interrupts electrical power to an outlet in the event of an unbalanced flow of current between the "hot" and the "neutral" sides of the outlet. Electronics within a GFCI outlet can detect the unbalance to between 5 and 25 mA, and subsequently opens both the hot and neutral sides by an internal DPST switch.

If a person is using a home appliance that becomes wet, the amount of current that can electrocute the person is unlikely to cause an ordinary circuit breaker to open. In a GFCI outlet, however, the small amount of current routed from the hot side of the outlet will be detected as different from that of the neutral side, resulting in the breaker interrupting the power to the outlet. In the US, GFCI outlets are required within one meter of any sink in all new homes today.

Electronic switch

Also called a *solid-state switch*, an *electronic switch* is one that is made of, or controlled by, an active electronic component, such as a transistor, an operational amplifier, or similar solid-state circuit. A unique feature of an electronic switch is the lack of physically moving parts. An outdoor motion detector, for example, can apply voltage to a transistor, which can control whether a camera starts taking a video of the person or animal whose motion was detected.

An electronic switch works on the principle that power to a circuit can be turned on or turned off "sufficiently"; that is, it can switch between a high-impedance state and a low-impedance state. This means, even when the solid-state switch is turned "off", power to the circuit might

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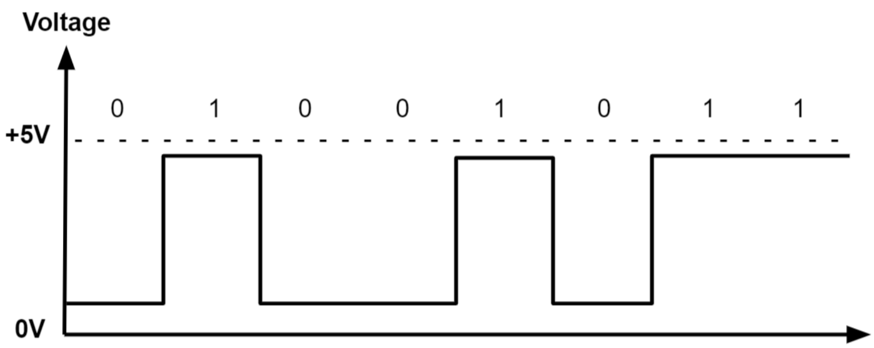
still be applied, but the current that flows into the circuit is considered negligible in the intended application. For example, inside a computer CPU (central processing unit) chip, numerous transistors constantly switch on and off (to each represent "one" or "zero"), but their "off" states are not "power turned off" states. (Note that this is unrelated to CPU P-state and C-state conditions, which affect the power source of the CPU as a whole.)



As you can see from the above digital logic state voltage diagram for, say, the output of a logic gate, the "low" voltage ("zero" bit) doesn't quite go down to zero volts. This non-zero voltage results in some minor *leakage current* between logic gates, but is within the acceptable region considered by the gate as a "zero" and does not affect gate function.

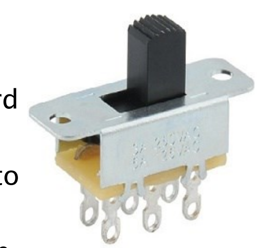
Common switches

The staggering number of switch varieties make a complete catalog here impractical, if not impossible. This brief and abbreviated list describes the most common switch types in use today, some listed by their primary means of mechanical operation.

Light switch—household toggle switch used for lighting and appliances

Momentary switch—normally remains open until pressed, like a keyboard key or a microphone PTT button or mouse click button

Slide switch—slide the switch to one end or the other, like a power switch to an amplifier



Slide switch

Soft switch—physical switch that activates an electronic switch, like the rubber power switch on a mobile radio or a small kitchen appliance

Limit switch—small switch that is normally closed (connected) until something pushes on its lever, interrupting the power, like the small switch at the top of an elevator, to turn off its power when it reaches the top floor

Rotary switch—rotating selector switch that allows multiple connections in several positions

Isolation switch—allows a low-voltage circuit to control a high-voltage circuit, like with a relay

Touch switch—activates when capacitively contacted by a finger, like a smartphone screen

Environmental control switch—allows environmental conditions to apply electrical power to an appliance or device, like a thermostat, motion detector, or life support systems

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Special-use switches

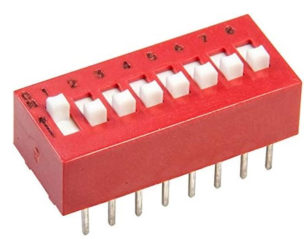
Some switches possess rather unique operations or styles, and are manufactured for special uses and applications. Here's a short list of a few of them:

- Keyed (ignition, LOTO)
- Pull-cord (light, variable-speed fan)
- DIP (dual-inline-package, can be a series of SPST slide or flip switches)
- Three-way light switch
- Externally controlled (thermostat, timer, dead-man)
- Relay (electrically isolates circuits)

Finally

If you need to design a circuit that contains a switch, you'll also have to consider a number of factors to help you make the right choice. Not all of them are important in every case, but some might be, for specific applications. Here are a few to keep in mind:

- Maximum voltage
- Maximum current
- Numbers of poles and throws
- Style (flip, rocker, slide, DIP, flat, toggle, push-button, knob, pull-cord, touch)
- Type (momentary, limit, rotary, dimmer, knife, isolation)
- Texture and tactility (membrane, touch, capacitive)
- Weather protection



DIP switch

Summary

A switch is an electrical device that's typically used to complete or interrupt a pathway of electrical power to one or more electrical circuits. Switches exist in numerous types; in fact, possibly more than any other electrical component. A switch can be a mechanically activated device, or it can be solid-state, in which there are no moving parts. The output of a mechanical switch must be debounced, if its signal is to be used as an input to a logic circuit. There are a number of switch features to consider when designing a circuit that uses one. Many switch types can be found redundantly listed in multiple groups, due to functionality, purpose, and design.

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